

# Heart Rhythm Monitoring in the Constellation Lunar and Launch/Landing EVA Suit: Recommendations from an Expert Panel



R.A. Scheuring, D. Hamilton,  
J.A. Jones, D. Alexander  
*NASA-Johnson Space Center*

# CONSTELLATION



# Acknowledgements



## ◆ Panel of cardiology experts

- Ben Levine, MD
- Steven Nissan, MD
- Michael Lauer, MD
- Richard L. Page, MD
- Paul Thompson, MD

## ◆ NASA and UTMB/Wyle Flight Surgeons

## ◆ NASA life science researchers

## ◆ EVA Physiology and Systems Project (EPSP) team

## ◆ HSIR specialists

- Tara Volpe, Duane Chin



# Purpose

- ◆ **Inform Space Medicine personnel of recommendations made by an expert panel of cardiovascular medicine specialists regarding in-suit ECG heart rhythm monitoring requirements during lunar surface operations**

# Background

- ◆ **Currently there are several physiological monitoring requirements for EVA in the Human-Systems Interface Requirements (HSIR) document**
- ◆ **Question as to whether the capability to monitor heart rhythm in the lunar surface space suit is a necessary capability for lunar surface operations**
  - Similarly, is the capability to monitor heart rhythm during a cabin depressurization scenario in the launch/landing space suit necessary?
- ◆ **Expert panel of cardiovascular medicine experts, including electrophysiology, exercise physiology, interventional cardiology and arrhythmia, convened on 29 July, 2008 to provide a recommendation to NASA**



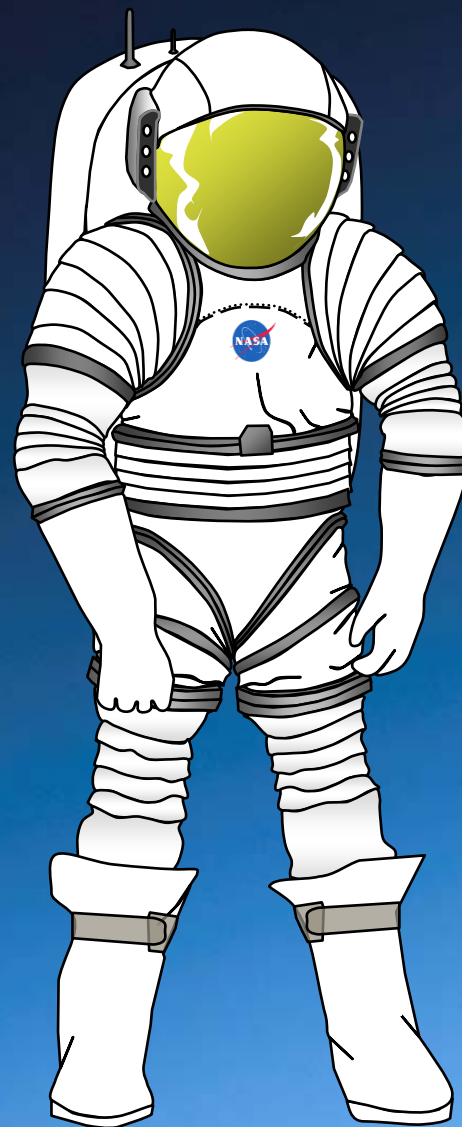
# Launch/Landing Space Suit

- ◆ **Crew will wear this suit for Earth to ISS transfer and lunar mission launches and landings**
  - Can also be used for contingency space walks to and from the moon
- ◆ **Has the capability to pressurize in the event of a cabin depressurization**
- ◆ **Injection port will be available for medication**
- ◆ **Heart rate monitoring capability will be built into the undergarment or via a commercial HR monitor**
  - Heart rhythm monitoring desired for contingency scenarios
    - Current implementation is via augmented limb leads
- ◆ **Data will be transferred to the vehicle via an umbilical attached to the suit**
  - Real time HR telemetry available to the ground

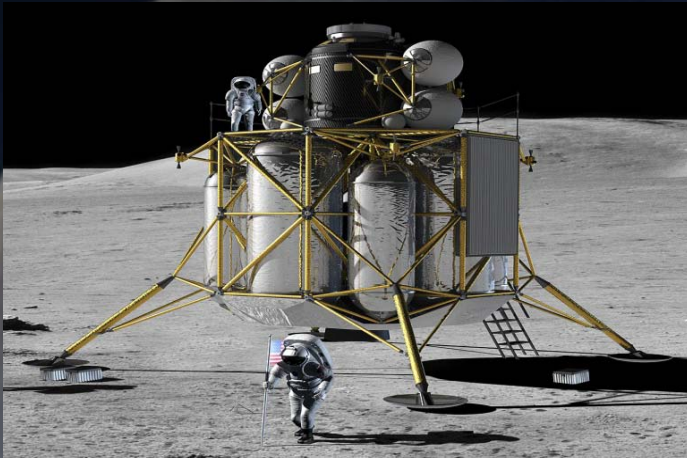


# Lunar Surface Space Suit

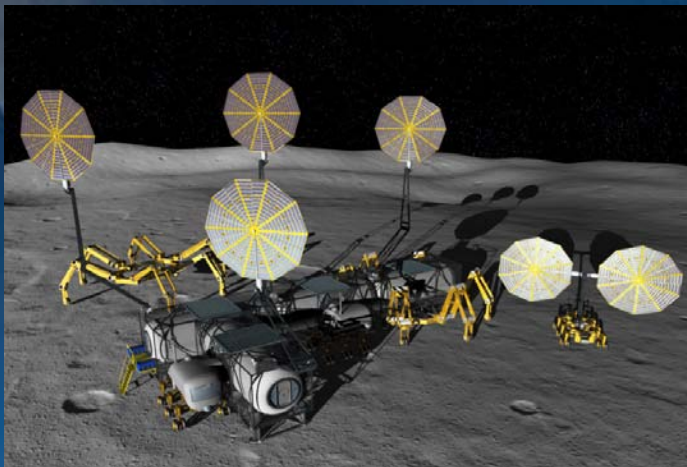
- ◆ **This suit will be worn on the lunar surface**
- ◆ **Suit will be pressurized to 4.3 psi in approximately 100% O<sub>2</sub> environment**
- ◆ **A liquid cooled undergarment will provide thermal control**
- ◆ **Real-time metabolic rates will be calculated from O<sub>2</sub> consumption and CO<sub>2</sub> production**
- ◆ **Heart rate monitoring, display and telemetry required**
  - Heart rhythm monitoring and telemetry are also required in this suit architecture
    - Rhythm implemented via augmented limb leads
- ◆ **1-May-09**



# Lunar Surface Vehicles



**Altair (Lunar Lander)**



**Lunar Outpost**



**Lunar Electric Rover (LER)**





# Materials Provided to Expert Panel



- ◆ **Current US astronaut corps demographic information including averages for**
  - Male/female age
  - BMI
  - SBP/DBP
  - Total Cholesterol
  - LDL
  - HDL
  - C-Reactive Protein
  - Documentation of a normal 2-D echocardiogram
- ◆ **Ranges for coronary artery calcium (CAC) scores for long duration astronauts**
- ◆ **Astronaut selection and retention standards (including testing provided and intervals for testing)**
- ◆ **Ranges for heart rate (HR) and metabolic (MET) rates obtained during microgravity and lunar EVA**
- ◆ **Clinical cases of terrestrial and in-flight arrhythmia in the US astronaut corps**
- ◆ **Technical discussion of current HSIR requirements for HR and ECG monitoring**
- ◆ **Suits being designed to have 2-channel augmented limb leads with derived third lead data in addition to HR monitoring**



# Clinical Cases in the Astronaut Corps

## • Astronaut Cases (current)

Number	Type	Event/Cause/Tx
– 1	Run of VT	ETT - Mitral Valve Prolapse with trace regurg
– 3	A Fib	Ablated
– 4/186		

## • During program (No Longer Active)

– 1	Sinus Bradycardia	ETT
– 2	SVT	ETT
– 1	Second degree AV Block	Lower body Pressure Testing
– 1	A Fib	Idiopathic
– 1	V Tach	ETT – No Ischemia
– 10/628		

## • Retired

– 1	A Fib	Idiopathic
– 1	SVT	Idiopathic
– 12/628		

# Panel Discussion

- ◆ **No uncontrolled hazard likely to occur in the suit during lunar surface or contingency microgravity ops that would require ECG monitoring**
  - However having the capability for rhythm monitoring inside the vehicle (IVA) was considered critical to manage an astronaut in distress
- ◆ **HR monitoring alone allows effective monitoring of astronaut health and function**
- ◆ **Negative aspects of rhythm monitoring**
  - Cost, complexity and reliability
  - Distraction of crew and engineers away from truly life-threatening aspects
  - Highly screened, healthy population with low pre-test probability of disease (majority of abnormalities would be artifact or clinically insignificant)
- ◆ **Exercise stress testing to an artificially determined 85% of max HR is inadequate for evaluating functional capacity or uncovering stress induced cardiovascular abnormalities**
  - Test should be performed to “symptom-limited” exhaustion

# Panel Discussion

- ◆ **Symptoms will occur concurrent with the arrhythmia in virtually all instances of significant cardiac arrhythmias**
  - Asymptomatic cardiac arrhythmias are most likely not pathological and not predictive for significant cardiac events in this highly screened and healthy population
- ◆ **2-channel augmented limb lead heart rhythm should not be considered as a monitoring tool for acute coronary syndromes**
- ◆ **Rhythm monitoring capability within the EVA or decompression suits is not an effective hazard control for the remote possibility of acute coronary events and would not affect the approach to an astronaut with chest pain**

# Panel Discussion

- ◆ **Cardiac atrophy may occur in a partial gravity environment with prolonged exposure and may alter the propensity for developing cardiac arrhythmias**
  - ECG monitoring for long duration lunar or Martian missions would necessitate the availability of rhythm evaluation in the context of the overall mission medical capability
  - Symptomatic cardiac arrhythmia would be best evaluated with 5-lead ECG (12 lead derived) in the vehicle as opposed to in the suit
- ◆ **Environmental factors potentially contributing to arrhythmia (lunar dust, radiation exposure) unlikely to cause acute events**
  - Long term exposure is unknown, however IVA ECG capability will mitigate these risks



# Panel Recommendations

- ◆ ECG monitoring capability as a clinical tool is not essential in the ESR2 configuration 2 (lunar) space suit
- ◆ ECG monitoring capability is not essential in the ESR2 configuration 1 (launch/landing) space suit for contingency scenarios
- ◆ Maintain current HR monitoring capability requirement for both ESR2 configuration 1 (launch/landing) and 2 (lunar) space suits
- ◆ Lunar vehicles should be required to have ECG monitoring capability with a minimum of 5-lead ECG (derived 12-lead) for IVA medical assessments
- ◆ Exercise stress testing for astronaut selection and retention should be changed from the current 85% maximum heart rate limit to maximal, exhaustive “symptom-limited” testing to maximize diagnostic utility as a screening tool for evaluating the functional capacity of astronauts and their cardiovascular health

# Addendum

- ◆ The panel recommendations do not address other potential lunar astronauts, which do not possess the described US astronaut cardiac risk profile
- ◆ “On demand” rhythm monitoring capability could aid in the diagnosis of potential health disturbances that could arise during the 144 hour unplanned pressure reduction suited lunar return scenario (e.g. electrolyte abnormalities, shock, etc.).
- ◆ There have been 13 cases of significant cardiac arrhythmias requiring management decisions in 628 US active astronauts; one case of ventricular tachycardia occurred on the lunar surface during suited EVA operations; but later coronary disease was found to be the root cause. Yet, of the remaining arrhythmia cases, 6 were asymptomatic at time of diagnosis; diagnosis usually occurring while being monitored for suited training operations or exercise fitness testing. Three cases of asymptomatic atrial fibrillation/flutter later required electrophysiological ablation, however these cases were not emergent in nature, and did not require immediate medical intervention.
- ◆ Is there something about the spaceflight environment that alters the risk for life-threatening cardiac arrhythmias that would be asymptomatic and picked up on routine monitoring during EVA?
- ◆ What are the best screening strategies for astronauts and space farers to ensure the lowest risk of catastrophic cardiac events during prolonged space travel?



# Back-Up

1-May-09

80th Aerospace Medical Association  
Scientific Program

# Addendum per Post Meeting Contributors and the Response of the External Panel



- ◆ **The panel recommendations do not address other potential lunar astronauts, which do not possess the described US astronaut cardiac risk profile**
  - *Both of these concerns raise the possibility that individuals who fly in space might have different screening procedures from the astronauts discussed by the panel. **In the opinion of the panel members, this concern is one of screening, rather than monitoring.** It would seem that a reasonable condition of allowing an individual to fly in space would be to have a normal 12-lead ECG, echocardiogram, and exercise test. If these basic screening tests are accomplished, then the risk of an astronaut having sudden cardiac death during an EVA is **probably <1:250,000 per year** if we use the data for athletes participating in competitive sports as an appropriate analogy. Of course this number could be higher if arrhythmia risk is increased in space flight, or lower if the risk of a low intensity EVA is less provocative than high intensity sports competition. Regardless, the panel members remain convinced that given the above screening minimums **this risk is not seen as high.***



# Addendum per Post Meeting Contributors and the Response of the External Panel



- ◆ **“On demand” rhythm monitoring capability could aid in the diagnosis of potential health disturbances that could arise during the 144 hour unplanned pressure reduction suited lunar return scenario (e.g. electrolyte abnormalities, shock, etc.).**
  - *This suggestion is a quite reasonable response to the panel’s original recommendations. In those recommendations, it was stated clearly that the panel members could conceive of situations where **the availability of rhythm monitoring could be clinically useful**. However **we could not justify the routine monitoring as essential to the health of the crew**. Information was presented to the panel suggesting that there are numerous constraints on ECG monitoring in the space suit, including engineering, logistics, distractions from the real risk of spaceflight (specifically creating a robust and relatively impregnable environment for the astronaut’s survival), and cost. **If these issues can be overcome from NASA’s standpoint, the panel sees no problem with having ECG rhythm capability “on demand.”** We would like to re-emphasize though, that in a highly screened population (even just with ECG, echocardiogram and exercise testing), any “abnormalities” identified in an asymptomatic astronaut during routine monitoring (e.g., extrasystoles, bigeminy, or short runs of other arrhythmias) **are likely false positive findings** (meaning they are unlikely to represent a serious underlying cardiac abnormality) and of **little clinical significance**.*

# Addendum per Post Meeting Contributors and the Response of the External Panel



- ◆ **There have been 13 cases of significant cardiac arrhythmias requiring management decisions in 628 US active astronauts; one case of ventricular tachycardia occurred on the lunar surface during suited EVA operations; but later coronary disease was found to be the root cause. Yet, of the remaining arrhythmia cases, 6 were asymptomatic at time of diagnosis; diagnosis usually occurring while being monitored for suited training operations or exercise fitness testing. Three cases of asymptomatic atrial fibrillation/flutter later required electrophysiological ablation, however these cases were not emergent in nature, and did not require immediate medical intervention.**
  - *The panel was aware of this background. The fact that sometimes individuals have asymptomatic arrhythmias identified during routine monitoring highlights the variable nature of cardiac arrhythmias, rather than makes a compelling case for routine monitoring during EVA. This knowledge does not affect the recommendations of the panel.*

# Addendum per Post Meeting Contributors and the Response of the External Panel



- ◆ **Is there something about the spaceflight environment that alters the risk for life-threatening cardiac arrhythmias that would be asymptomatic and picked up on routine monitoring during EVA?**
  - *The evidence to date supporting a clinically meaningful change in arrhythmia substrate is meager, though this is the focus of an ongoing investigation by a number of cardiovascular investigators funded by NASA. More important is the concept that monitoring of asymptomatic crew members during routine EVA procedures is not the way to identify or treat such conditions. It was, and still is the opinion of the panel that having the capability to bring a symptomatic crew member back to the vehicle where more comprehensive ECG assessment could be performed IS an essential capability, but routine monitoring is not. If however “on demand” rhythm monitoring could be made available at reasonable logistics and cost, the capability could prove useful in the differential diagnosis of an astronaut in distress.*

# Addendum per Post Meeting Contributors and the Response of the External Panel



- ◆ **What are the best screening strategies for astronauts and space farers to ensure the lowest risk of catastrophic cardiac events during prolonged space travel?**
  - *The panel members are of course quite familiar with the diseases outlined in the full question, and their risks of causing sudden death during exertion. However as noted above, the more appropriate response to this concern is establishing minimal screening criteria, such as a 12-lead ECG at rest and during exercise, and an echocardiogram. If all of these are normal, the risk for sudden death during exercise is extremely low, and not likely to be altered by routine monitoring during EVA.*





# Expert Panel



- ◆ **Chair: Benjamin D. Levine, MD – Director, Institute for Exercise and Environmental Medicine, Professor of Medicine and Cardiology, University of Texas Southwestern Medical Center at Dallas; Team Lead, Cardiovascular Alterations for the NSBRI**
- ◆ **Michael Lauer, MD – NHLBI Director, Division of Prevention and Population Sciences**
- ◆ **Richard L. Page, MD – Head of Cardiology, University of Washington**
- ◆ **Steven Nissen, MD – Director, Cardiology, Cleveland Clinic Foundation**
- ◆ **Paul D. Thompson, MD – Chief of Cardiology, Hartford Hospital and Professor of Medicine, University of Connecticut**



# Other Participants



## ◆ Flight Surgeons

- JD Polk
- James Locke
- Terry Taddeo
- Doug Hamilton
- David Alexander
- David Gillis
- Rick Scheuring

## ◆ Engineering

- Mike Lewis (GRC)
- Duncan Atchison (ARC)
- DeVon Griffen (GRC)
- Jimmy Wu (Wyle-JSC)
- Steven Chappell (EPSP-JSC)

## ◆ Space Life Sciences

- Jonathan Clark, MD (NSBRI)
- David Baumann (JSC)
- Steven Platt, PhD (JSC)



# Forward Work



## ◆ Delete Heart Rhythm from HSIR EVA requirements:

- 3.10.5.1 Measurement of Physiological Parameters [HS11015]
- 3.10.5.2 Display of Physiological Parameters [HS11016]
- 3.10.5.3 Alert for Off-Nominal Physiological Parameters [HS11017]
- 3.10.5.4 Telemetry for Physiological Parameters [HS11018]